The study of measuring methods for electrical resistance

VALENTIN DOGARU ULIERU
TRAIAN IVANOVICI
ADELA GABRIELA HUSU
Electronics, Telecommunications and Energetic Department
VALAHIA University of Targoviste
CAROL I, no.2, Targoviste, ROMANIA
dogaruvalentin@gmail.com, traian_20@yahoo.com, adelahusu@yahoo.com

Abstract: - Measurement and automation technology were changed once the National Instruments company introduced the concept of virtual instruments, using the graphical programming LabVIEW (Laboratory Virtual Instrument Engineering Workbench). LabVIEW, originally developed for the measurement and automation technology, has been advancing more and more as an alternative to conventional programming languages. This graphical programming represents crucial reading and work for instructors, scientists, students, hardware and software developers, and decision-makers in research, academia and industry. This article presents theoretical considerations regarding electrical resistance measurement in D.C. circuits and applications for their study and analysis using the LabVIEW graphical programming.

Key-Words: - LabVIEW, virtual instruments, electrical resistance, ohmmeter, indirect methods, Wheatstone.

1 Introduction

Computer-aided teaching tools have turned out to be an indispensable element of both classroom lectures and laboratory experiments. The application of market-ready mathematical and database programming software for teaching engineering course outline is well appreciated. This paper presents the utilization of *LabVIEW* (Laboratory Virtual Instrument Engineering Workbench) in the study of measuring methods for electrical resistance. The undergraduate students need minimal acquaintance of a programming language.

For more than 10 years, LabVIEW has revolutionized the way engineers and scientists in industry, government, and academia approach measurement and automation. Leveraging PCs and commercial technologies, virtual instrumentation increases productivity and lowers costs for test, control, and design applications through easy-to-integrate software, such as NI LabVIEW, and modular measurement and control hardware for PXI, PCI, USB, and Ethernet. With virtual instrumentation, engineers use graphical programming software to create user-defined solutions that meet their specific needs, which is a great alternative to proprietary, fixed functionality traditional instruments. Additionally, virtual instrumentation capitalizes on the ever-increasing performance of personal computers. For example, in test, measurement, and control, engineers have used virtual instrumentation to downsize automated test equipment (ATE) while experiencing up to a 10 times increase in productivity gains at a fraction of the cost of traditional instrument solutions. Because LabVIEW has the flexibility of a programming language combined with built-in tools designed specifically for test, measurement, and control, you can create applications that range from simple temperature monitoring to sophisticated simulation and control systems. No matter what your project is, LabVIEW has the tools necessary to make you successful quickly.

Virtual instrumentation is applicable in many different types of applications, starting from design to prototyping and deployment. The LabVIEW platform provides specific tools and models to solve specific applications ranging from designing signal processing algorithms to making voltage measurements and can target any number of platforms from the desktop to embedded devices – with an intuitive, powerful graphical paradigm.

It is indispensable to emphasize the engineering education curriculum with computer-aided teaching tools that are interactive as well as educational, in order to keep sustainable interest in the learning process for the students. For these reasons LabVIEW, a graphical programming language was introduced to initiate the modifications in teaching methodology.

LabVIEW is a graphical programming language that shares some aspects with traditional non-graphical programming languages (C, Pascal etc) and some aspects of hardware definition languages (VHDL, Verilog). Namely, it combines the generality and power of traditional programming data structures such as loops, if-then branches, and arithmetic operators with the ability of hardware definition languages to perform simultaneously multiple tasks.

2   Generality

In technique is necessary to measure different types of electrical resistance, often meet is: linear resistance, nonlinear resistance, parametric resistance, and dynamic resistance, resistance in D.C. or A.C. The difficulties in making of measurement methods and resourceless are amplified by very large measurement range. It must assure contact resistance measurement $(10^{-8} - 10^{-7}\,\Omega)$ also of an isolation resistance $(10^{17} - 10^{18}\,\Omega)$. For every range, any measurement methods are specific, pursuing elimination of parasite resistance influence. From these above mentioned, it results that the measurement methods of electrical resistance have to be very varied and the choice of any method depends on the size order for resistance and on the accuracy with which is desired for the obtained result. The resistance can be measured by direct, indirect, comparative, bridges methods. In alternative current the resistivity for receiver is not constant, it varies with reversed stress, because the absorbed active power is modified with frequency, due to the existence of film effect, the proximity effect, the loses through back-set as well as hysterezis.

3 Direct method – measurements with ohmmeter

Ohmmeters are used at electrical resistance measurements in very large range of values $(\Omega…M\Omega)$ also at circuits continuity test. Their accuracy is low but the needs of measurement / rapid troubleshooting of circuits. There are frequently meet in multimeter structure and rarely as individual device (for high resistance measurement).

Analogical Ohmmeter directly indicates the value of resistance measured with removal of a pointer in front of a graduated scale. Measurement is based at evaluation of the current that runs through the measuring resistance and the device scheme has to contain the magneto-electric instrument indicator, continuous power supply (battery, generator dc), resistors for protection and magneto-electric instrument for measuring change intervals.

Ohmmeters with serial scheme are the most spread, being used for the measurement of resistance in range $10 - 10^6\,\Omega$. Electrical scheme for the device is presented in figure 1. Power supply provides the voltage U, R_0 resistance is making null adjustment of the instrument magneto-electric (U not stabilized) and $R_1…R_n$ resistance are used for measuring the change interval ohmmeter.

Considering all switches open, the deviation of the instrument has the expression:

$$\alpha = \frac{U}{C_i}\frac{1}{R_0 + R_i + R_X} \tag{1}$$

and static characteristic $\alpha = f(R_X)$ has the hyperbolic character and the scale is non-uniform and reverse. The maximum deviation is obtaining for $R_X = 0$ (The switch K is closed):

$$\alpha_{max} = \frac{U}{C_i}\frac{1}{R_0 + R_i} \tag{2}$$
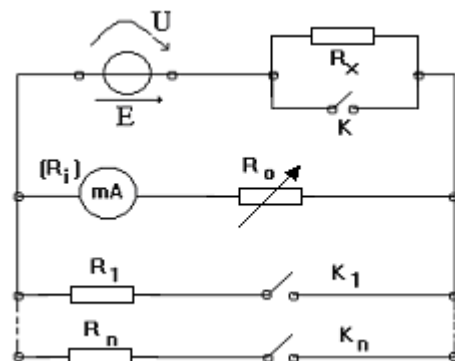

Fig. 1. Serial ohmmeter- diagram.

And minimum deviation is obtaining for $R_X \to \infty$, having the value $\alpha_{min} = 0$.

Graduated scale device is reversed, the deviation $\alpha = 0$ corresponds to $R_X \to \infty$ and deviation $\alpha = \alpha_{max}$ corresponds at $R_X = 0$. The adjustment at $\alpha = 0$ is made by variation of R_0 with K switch closed. The change of measurement range is made by introduction in circuit of one of $R_1…R_n$ resistance.
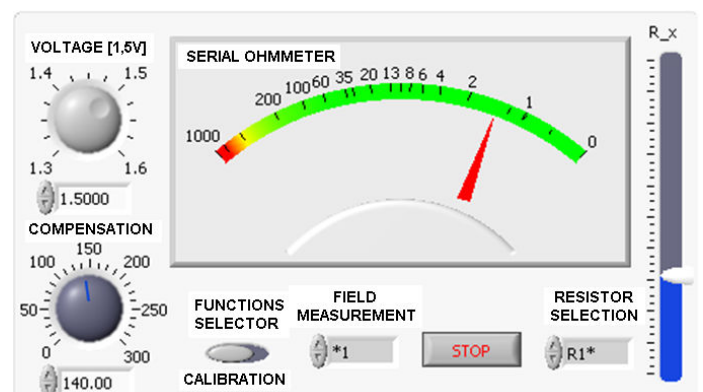

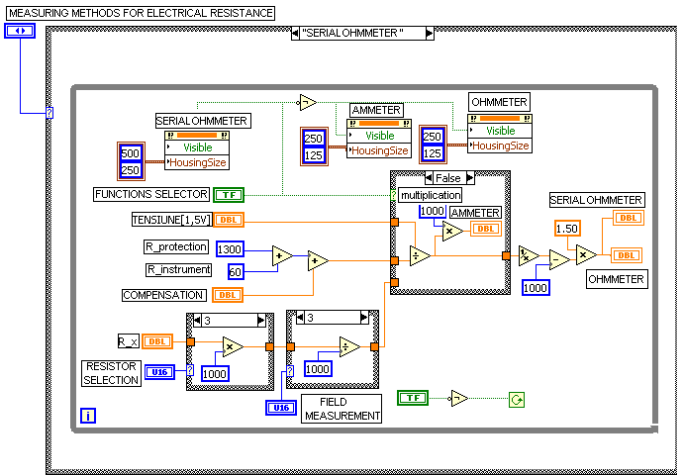Fig. 2. Serial ohmmeter –LabVIEW application, front panel

Fig. 3. Serial ohmmeter –LabVIEW application, block diagram

Graduated scale device is reversed, the corresponding deviation and the corresponding deviation.
For ohmmeter error calculation it must, considering that instrument magneto-electric device have a certain report error, conforming to accuracy class:

$$\varepsilon_{rI} = \frac{\Delta I}{I_{\max}} = \frac{\Delta \alpha}{\alpha_{\max}} \tag{1}$$

because:

$$\Delta \alpha = \left| \frac{\partial \alpha}{\partial R_X} \Delta R_X \right| \tag{2}$$

results:

$$\Delta \alpha = \alpha_{\max} \frac{R_0 + R_i}{\left(R_0 + R_i + R_X\right)^2} \Delta R_X \tag{3}$$

and relative error for resisting measure has the following expression:

$$\varepsilon_{rR_X} = \frac{\Delta R_X}{R_X} = \varepsilon_{rI} \frac{(R_0 + R_i + R_X)^2}{(R_0 + R_i)R_X} \tag{4}$$

The minimum of the error is obtaining for $R_X = R_0 + R_i$, so at the middle of the scale and has the value:

$$(\varepsilon_{rR_X})_{\min} = 4\varepsilon_{rI} \tag{5}$$

To extremity the error goes to the infinite. As result, for the measurement error of a resistance with serial ohmmeter to be smaller is necessary the choice of a measurement range so that the reading to be made in central area of a scale.

4 Indirect methods

4.1. Substitution method
Substitution method consists in unknown resistance comparison R_X with a known resistance R_e through ammeter or voltmeter. In figure 4 is indicated the measurement schemes, unknown resistance putted in parallel with a precision adjustable resistance R_e with a known value. The method involves two successive measurements, the resistance for measure R_X being replaced with resistance R_e, which is adjusted until the same indication of the device for both positions of switch K is obtained. The value for measurement resistance is equal with adjusted R_e resistance.
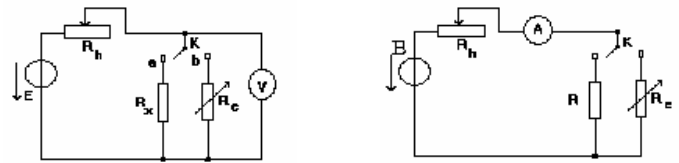

Fig. 4. Substitution method using: voltmeter, ammeter.

4.2. Indirect method of ammeter and voltmeter
The determination of resistance through this method is based by Ohm law: $R_X = U_X / I_X$. It is necessary to be measured the voltage at the resistor terminals and inside current, then the resistance is calculated. After connecting mode of a voltmeter, it can be used upstream or downstream assembly.
In upstream assembly the result is:

$$R_X = \frac{U - U_A}{I} = \frac{U}{I} - R_A \tag{6}$$

If the unknown resistance is calculated only from both devices indications, without considering the internal resistance of ammeter, it is as a systematic error:

$$\frac{\Delta R_X}{R_X} = \frac{\dfrac{U}{I} - \left(\dfrac{U}{I} - R_A\right)}{R_X} = \frac{R_A}{R_X} \tag{7}$$

The error decreasing imposes condition such as $R_X \rangle\rangle R_A$, so the upstream assembly is used for big resistance measurements.
Using the right term, the relative error limit is:

$$\frac{\Delta R_X}{R_X}(\%) = \left(\frac{\Delta U}{U} + \frac{\Delta I}{I}\right)\left(1 + \frac{R_A}{R_X}\right)100 \tag{8}$$

where:

$$\frac{\Delta U}{U} = \frac{c_V U_{\max}}{100} \tag{9}$$

$$\frac{\Delta I}{I} = \frac{c_A I_{max}}{100} \qquad (10)$$

represent the relative errors of the using devices.
For the upstream assembly:

$$R_X = \frac{U}{I - I_V} = \frac{U}{I - \dfrac{U}{R_V}} \qquad (11)$$

The same for upstream assembly, the systematic error is:

$$\frac{\Delta R_X}{R_X} = \frac{\dfrac{R_X R_V}{R_X + R_V} - R_X}{R_X} = -\frac{1}{1 + \dfrac{R_V}{R_X}} \qquad (12)$$

As that error to be small it is necessary to $R_X \langle\langle R_V$, so the upstream assembly is used for small resistance measurement. The relative error limit is:

$$\frac{\Delta R_X}{R_X}(\%) = \left(\frac{\Delta U}{U} + \frac{\Delta I}{I}\right)\left(1 + \frac{R_X}{R_V}\right)100 \qquad (13)$$

Tacking into consideration some theoretical aspects an application has been made. This application gives the possibility for method analysis, having the following facilities: measurement range selecting at ammeter and voltmeter, the accuracy class of the devices selecting, tension and current change for measurement of different values resistance, measurement method selecting and specifying which method has to be used as well as the error calculation.
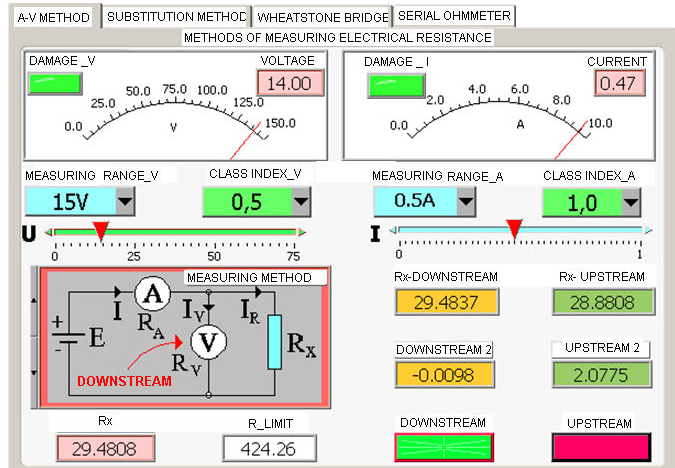

Fig. 5. Electric resistance measurement with ammeter and voltmeter LabVIEW application

The observations at that measurement method are:
- the errors are percentage, so the method don't have a high accuracy;
- for minimal limit errors, at the resistance measurement

with ammeter having the R_A resistance and with a voltmeter having the resistance R_V, it was chosen the assembly:

- upstream, if $\quad R_X \langle \sqrt{R_A R_V}$
- downstream, if $R_X \rangle \sqrt{R_A R_V}$

- it is the only applicable to nonlinear resistance method (arc, incandescence lamps, discharge in gas pipes, semiconductors etc) also at internal resistance measurement of direct current sources. For example, figure 6 presents measurement and determination of electrical lamp with incandescence characteristics for the cars, using an acquisition date system made with PCI 6023 XE.
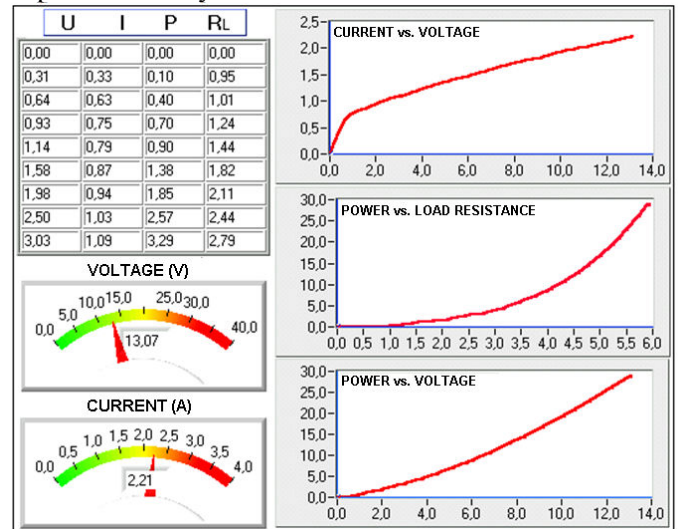

Fig. 6. The determination of unlinear resistors characteristics – LabVIEW application

5 Link methods for electric resistance measurement - Wheatstone in well-balanced regime

The measurement method principle of the unknown resistance X consist in equalization of the Wheatstone through resistance R variation, the equalization moment is relieved by galvanometer indicator $I_G = 0$. In this situation the C and D points have the same potential:

$$U_{CD} = 0 \rightarrow aI_1 = bI_2 \quad \text{and} \quad XI_1 = RI_2 \qquad (14)$$

Result the equation which lead to unknown resistance calculation:

$$X = R\frac{a}{b} \qquad (15)$$

Conforming with this result it can be built Wheatstone with:
- $R = \text{constant}$ and $a/b = \text{variable}$;
- $a/b = \text{constant}$ and $R = \text{variable}$, this type being the most used.

Because R have a discreet variation, the R_e value can't be obtained and it is reached two closed values, R_1 and R_2 corresponding for left and right by-pass to zero position.

In that situation R_e it is approximate by interpolation resistance:

$$R_i = \frac{R_1\alpha_1 + R_2\alpha_2}{\alpha_1 + \alpha_2} \qquad (16)$$

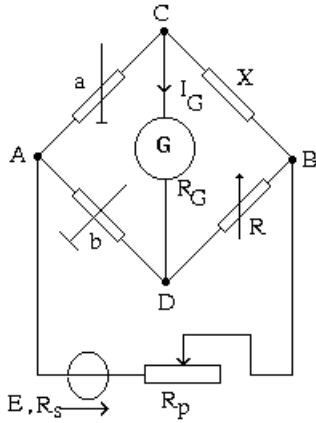Principle electrical scheme is presented in figure 7, and the LabVIEW application in figure 8.

Fig. 7. Wheatstone

a,b – Wheatstone resistance (1,10,100,1000)Ω;
R - resistance decade 10 x(0,1+1+10+100+1000)Ω;
X – resistance for measurement ;
R_G – galvanometer resistance;
R_S – internal resistance of source;
E - voltage of electric source;
Rp- protection resistance.

The application is made for measurement of unknown resistance having the facilities: resistors values selection R_1, R_2 (10; 100; 1000Ω) which give the possibility to increase the accuracy of Wheatstone; sensibility change (*1; *10; *100; *1000); the decade resistor utilization 0 ÷ 11111,0; utilization of the null analogical pointer; logic signalling of the result of comparison between unknown resistance with standard resistance.
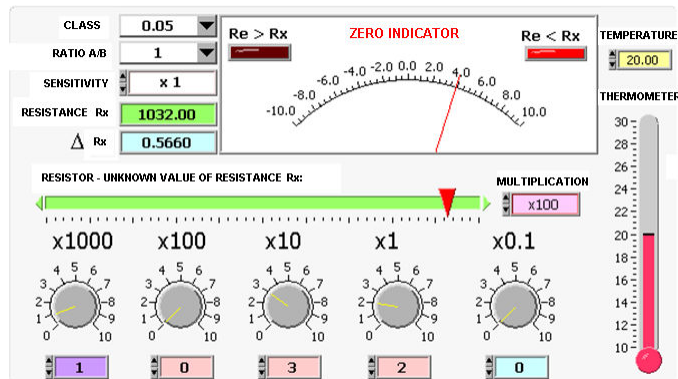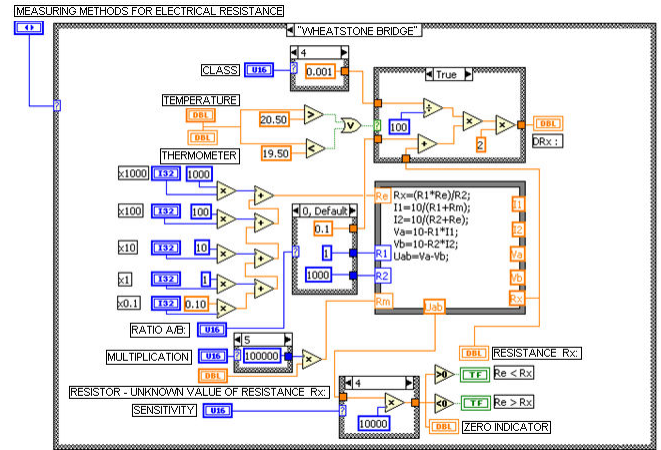

Fig. 8. Wheatstone bridge – front panel

Fig. 9. Wheatstone bridge – block diagram

6 Conclusions

Using of LabVIEW, the analysis and the study of the electric resistance measurement methods in D.C. is assured. This analysis is based on the presented theoretical reason, being very useful in lab application. The made applications allow the input parameters change by means of the specific control elements, the choice of measurement method and determination of nonlinear resistors characteristic.

References:
[1] R. Jamal., L. Wenzel, *The applicability of the visual programming Language LabVIEW to large real-world applications*, Proceedings of the IEEE Symposium on Visual Languages 1995.
[2] G. Bengu and W. Swart, *A computer aided, total quality approach to manufacturing education in engineering*, IEEE Trans. Educ., vol. 39, Aug. 1996.
[3] Andrei. H., et al. – *Electric circuit theory*, Printech Publishing House, Bucharest, 1999.
[4] Cepisca, C., s.a – Methods and means of measurements *Metode si mijloace de masurare,* Sfinx2000 Publishing House, Targoviste, 2001.
[5] Dogaru-Ulieru,V., s.a.- *LabVIEW applications in measurement,* CONPHYS Publishing House, Rm. Valcea, 2002.
[6] Ertrugul, N. – *LabVIEW for electric circuits, machines, drives, and laboratories*, Pretince Hall PTR, NJ, 2002.
[7] *** National Instruments, LabVIEW – *User Manual, LabVIEW – Data Acquisition Basics Manual, Academic Resources* , 2003.
[8] *** www.ni.com